Digital Image Processing and the Recording of Rock Art

Phil Clogg and Margarita Díaz-Andreu

Department of Archaeology, University of Durham, U.K.

Brian Larkman

School of Law, Arts & Humanities, University of Teeside, U.K.

(Received 26 March 1999, revised manuscript accepted 26 October 1999)

With the advent of low-cost, high-powered computers, access to digital image processing is becoming more common and within reach of every researcher. Many techniques are available to extract information by computer manipulation of images and, therefore, this approach has great potential for the study of rock art. Processing procedures such as selective contrast enhancement, study of detailed areas, edge enhancement, multiple image superimposition etc. provide a broad range of tools that can greatly enhance our understanding of rock art. As all of the processing and analysis can be done in the laboratory these techniques are also very cost effective. In addition, they provide a non-destructive method of recording and analysing rock art. The potential of image processing techniques will be illustrated by reference to the post-Palaeolithic rock art of the site of Selva Pascuala (Cuenca, Spain).

Keywords: DIGITAL IMAGE PROCESSING, ROCK ART, RECORDING.

Introduction

The history of rock art studies has been characterized by a continuous search for reliable and accurate recording techniques. At present the most common of these are the tracing of pictographs and/or the rubbing of petroglyphs. In practice the techniques are applied by different research groups following different procedures, each of which is claimed to be the most effective. Both tracing and rubbing, however, have several problems, the most important of which is the danger of damaging the art itself.

Other less intrusive techniques have found occasional use for recording. Photography, for example, has usually been employed only to support other techniques, often just to serve as illustration for a text. Photography has obvious advantages, however, not only because it implies an always helpful cut in fieldwork costs, but also because the art is more readily available to the researcher. In addition the use of photography greatly decreases the danger of damaging the art, and could be said to provide a more objective recording. Nevertheless, its use has been limited, mainly because of the problems entailed in its practical application. This is largely dependent on the skill of the photographer, both in the field where factors such as lighting, focus and exposure that greatly influence the results must be balanced, and in the darkroom where complex chemical processing techniques must be used to enhance the images and reveal hidden detail.

Recently the effectiveness of photography for recording and analysis has been greatly enhanced by the development of “computer-aided” or “digital” image processing (DIP) techniques. These involve reducing an image to an extremely fine grid of square picture elements or “pixels”, each of which is given a colour value that can be analysed digitally by computer, thus processing images very much faster than the traditional chemical methods and allowing a huge range of sophisticated effects to be obtained. With the advent of low-cost high-powered computers, access to digital image processing has become more common and within reach of every researcher. In this paper we will discuss a particular set of techniques provided by DIP that can overcome the problems inhibiting the use of photography for rock art recording and analysis. We will restrict our description of its application here to that of the recording of painted rock art. The use of DIP in this context retains all the advantages of photography and at the same time allows the user to overcome many of its disadvantages. An example of this is how in DIP, control over the image increases dramatically, because image processing allows the user to enhance overall contrast and sharpness producing greater definition for human perception. The manipulation of images is also made easier using digitization.
so that faint, obscured and damaged features can be revealed. Similarly, problems such as poor control of lighting can be corrected to some extent and detailed areas can be more easily examined by large-scale enlargement if the resolution is high enough. Because of this, the technique does not rely upon the perfect photograph (although obviously this does not excuse the taking of poor photographs!).

Digital image processing has just been put into practice by several teams all over the world, and everything points to the fact that this technology is going to be widespread in a few years. Related systems employed by other teams include the use of digital interferometry to record the art and the surface shape (Bertani et al., 1997) and the use of commercially available paint package such as Corel Graphics, Adobe PhotoShop and Micrograph Publisher and Ermapper (Vincent et al., 1997; Mariano, 1998; Montero Ruiz et al., 1998). Since 1997 several members on the online rock art discussion group have pointed to other software used in the recording of rock art: Dimple, NIH Image, as well as PCI.

In this paper, we will discuss the development of a technique for recording rock art using DIP. The system available within the Department of Archaeology of the University of Durham is based upon a Pentium II processor running at 350 MHz with 128 Mbytes of RAM. The photographic slides are digitized at a resolution of 2700 dpi and the image manipulation is undertaken using the PC IMAGE PLUS processing and measurement package produced by Foster Findlay Associates. The chosen software is used in conjunction with a C image function library, thus allowing modifications to be made by the user to the standard processing techniques. Although the software is capable of full colour (24 bit) manipulation, we chose initially to work in the grey-scale domain. This restriction in operating parameters was considered appropriate in order to facilitate the development of a robust methodology as applied to rock art which would form a base line from which further refinements and an expansion into full colour were possible with maximum efficiency.

The image chosen to illustrate our work comes from the Selva Pascual shelter, one of the rock art sites in Villar del Humo, province of Cuenca (Spain). This area is peculiar from a geological point of view, as the bedrock of its mountainous landscape is an attractive red sandstone which contrasts sharply with the green forest surroundings. From its discovery in 1917, the site has been recorded on several occasions (Hernández Pacheco, 1959: fig. 365; Dams, 1984: fig. 119; Collado Villalba et al., forthcoming a, b, the latter recording copied in Romero Sáiz, 1996: 179; see Figure 1). In the first two cases tracing techniques were probably used and in the last case microphotography, drawing the result using AutoCAD (Collado Villalba pers. comm.). In this shelter 32 motifs are found. They are anthropomorphs, zoomorfs and signs made in levantine and schematic styles. The image with which we have worked, a bull, was taken in April 1998 by Margarita Diaz-Andreu (Figure 2). The apparent good conservation of the motif contrasts with the contradictory published recordings. This is an ideal choice, therefore, on which to experiment and illustrate the advantages and problems of digital image processing applied to the recording of rock art.

Digital Image Processing and the Recording of Rock Art: Preprocessing

Our overall aims are to investigate and enhance poorly defined areas within the image and extract all information pertaining to the motifs in a form which can best present our interpretation of the rock art. Two major stages can be defined in the application of digital image processing: the preprocessing and the processing.

In an ideal world preprocessing the image should not be necessary. In the real world, however, images have a series of problems that have to be dealt with in order to facilitate the processing of the image. These problems relate essentially to the base (i.e. rock) on which the pictographs are painted, the light and the condition of the painting itself. The natural variations in the colour and the texture of the rock can interfere and cause problems in the definition of the image. This gives rise to the appearance of a noise that impedes an easy digital treatment to the painted motifs. The light is an obvious problem in the manipulation of carved images, because of the effect of the shadows. With reference to

Figure 1. (a) Recording by Dams (1984: fig. 119); (b) recording by Collado Villalba et al. (forthcoming a, b).
the painting, the variation in pigment density across the motif may interfere with the digital treatment of the image. In addition, some areas of the painting have been washed down by the effect of water, and this obviously presents problems, first in defining the edges of the motif (i.e. in deciding what is the background and what is the art) and, second, in the decisions on how to represent it.

In our example, both the colour of the rock and the paintings are red, and this coincidence obviously affects the ease with which the features can be discriminated. To this it should be added that there are slight variations between the colours chosen for each motif, that the density with which the painting has been applied in different areas of the figure is variable, and finally that, although it does not seem to affect the painting to a high degree, in some areas the painting appears to have been washed down. In terms of the surface, despite it being roughly flat, the granulate structure of sandstone and its layered composition influence the reading of the image. Moreover, there are a few places in which the surface is very irregular, due to a breach and also because of a few hollows, which in our case mainly affects the area around one of the rear legs of the bull. This particular problem not only affects the use of image processing techniques but has also caused problems in previous recordings, as those by Hernández Pacheco (1959: fig. 365), Dams (1984: fig. 119) and Collado et al. (forthcoming a, b) show a more incomplete recording for this leg than for the other ones (Figure 1).

The nature of rock art is such that each image is unique and has its unique problems. Because of this no one single processing method can solve these problems and invariably we require the use of a number of tools which either complement each other or work on specific areas or problems. The array of techniques available within DIP is vast and therefore we consider that a structured approach is necessary in order to maximize both efficiency and the extraction of information.

First Approach: Working with the Image as it Stands

In our example, we began by processing the whole image (Figure 2). This is particularly of interest when previous recordings are available and there are areas of uncertainty or conflicting features. Our aim at this stage was to highlight the information which was not obviously visible. In the first place, problems of variation in lighting and shadows may be overcome to a certain extent by the use of a variation of the Wallis algorithm (1977). This will automatically adjust the brightness and the contrast of small areas within the image in order to produce an image in which all of its sections have an equal overall brightness and contrast.

A number of standard techniques can then be applied in sequence. These techniques are available in most software packages, the main ones being contrast enhancement, edge enhancement, and image sharpening. Contrast enhancement, which may operate within the image by the use of either look-up tables or histogram modifications, can establish greater separation of the paint from the background. Secondly, edge enhancement is able to accentuate edge details and so provide greater definition within the image; for example, the boundary between the paint and the rock.
Thirdly, high-pass filters are designed to sharpen details or enhance areas which are blurred.

Furthermore, the use of the random colour look-up tables is a procedure which is not time consuming but can easily serve to emphasize features that may warrant further investigation. The use of this technique is motivated by the fact that the human visual system is able to discern a vast range of colour shades and intensities compared to approximately 60 to 90 JND (just noticeable differences) in a grey scale. This facilitates the identification of details and can also present the image in an unconventional manner, thus challenging our preconceived ideas of what we are seeing. For example, in the chosen image, previous recordings had ignored some dots that we believe are significant at the top part of our image, and have proposed very different recordings of the bull, for example his hooves, the line of his shoulders, his horns, sex, tail, etc., and in particular of the archer over him.

After having used the random colour look-up tables some further information was suggested and we agreed with Dams (1984) on the possibility of the bull having had another horn (perhaps the result of a previous painting?). In terms of the line over the bull’s shoulders our results are not conclusive of whether this is a feature of the rock or the result of a previous painting. A further field visit would be necessary to check this particular detail. Similarly the look-up tables were unable to clarify details of the hooves and further processing was considered necessary.

**Second Approach: Trying to Remove the Background Interference**

Removal of the background interference, i.e. the texture of the rock itself, is a difficult task to accomplish given the random patterning of the natural material. However, one line of enquiry would be through the processing of the image using multiple image operations. These operations are used to superimpose two or more images, the pixel values of one image being either added or subtracted from the corresponding values of a second image. The successful use of either technique is dependent upon the nature of the original image. In image subtraction an image processed using a low-pass filter to blur the details of the background is subtracted from the original image, thus highlighting the high frequency components within the image, i.e. those associated with edges and details.

One of the problems with using this technique is the slight fuzziness to the edges of the motif. However, in our example, the possible horn in the middle, which could even be accompanied by another one, appears more apparent. The addition of a further image processed using edge enhancement to the previous image produces a sharpness to the boundaries of features and further reduces the effects of the background (Figure 3(a)). We can see that the background has been reduced to an even grey surface, which further enhances the outline and details of the bull. Note particularly how the tail, the hooves and the possible previously painted horns become more apparent. We consider this as possibly the clearest representation of the bull that we have so far produced.

**Preprocessing Stage 2: Edge Detection and Thresholding**

Another method of extracting information from the whole image is using the technique of edge detection. Edges within a digital image are defined as the boundary between pixels with highly contrasting values.
Filters can be applied which enhance these boundaries, thus providing outlines of features within the image. The most effective of these is the sobel filter which picks up edges in all directions (Figure 3(b)). Unfortunately these filters are not selective and, therefore, much extraneous information is also highlighted. In our example, we have overcome this problem to some extent by previous processing of the image, which has removed some unwanted detail. The sobel filter produces an outline of the image. To facilitate interpretation it is often necessary to superimpose the sobel image onto the real image in order to highlight the relationship between the two. Once this has been accomplished a threshold function can then be applied to the sobel image, thus producing a binary image superimposed upon the original (a binary image is one which is composed of only two colours thus giving a high definition to any motif) (Figure 3(c)). By using a technique termed Skeletonise in the PC Image program the lines within the binary can be reduced to a width of one pixel, thus providing a high level of detail (Figure 3(d)). The image can then be filtered automatically to remove any information below a predefined size producing a detailed outline of the major features. At this point we found that there are always a number of discontinuities within the outline and that some of the less well defined detail is missing (for example the tail). To complete the image at this stage would require a good deal of manual editing, something which we feel should be avoided, and so whilst this sequence shows some potential we consider that further development is necessary for its full realization.

Preprocessing Stage 3: Checking Problematic Areas

In terms of checking these problematic areas two different and complementary procedures can be followed; either zoom into the feature or enclose it in a “region of interest”. The amount of detail revealed when magnifying digital images is dependent upon the original resolution used at the time of digitization, i.e. how fine was the initial grid applied to the image. Zooming into an image only increases the size of the pixels present so that eventually, at high levels of magnification, a distinct chequer-board effect is visible. In other words, zooming into areas within the image can only reveal small details on very high resolution images.

The second method to investigate problematic areas is to enclose them in “regions of interest”. Many processing techniques examine the overall values of an image, averaging the results of dissimilar areas. Creating localised “regions of interest” allows any processing techniques used to concentrate on one area and ignore the mass of the background, avoiding introducing any imbalances into the algorithms used. The techniques used on the region of interest, therefore, are more focused on the value of the pixels of that area and ignore those of others.

Several techniques can be used once a region of interest has been defined. First of all, some of the extraneous noise is removed using a median filter. This operates by eliminating any isolated intensity points within the area without significantly blurring the image. Once this is done, a histogram equalization may be employed to maximize the contrast within the area. This procedure works by reassigning the intensity values within the region in order to produce a flat histogram, stretching the pixel values over the range of 0 to 255. (In a normal digital grey-scale image there should be 256 levels of grey between black and white if visible “steps” are to be avoided.) This can dramatically increase the dynamic range of the region and in this way accentuates the contrast. In our case this did not produce a visible difference within the image, indicating this to be a well defined area.

The following step is to zoom up the image to enlarge the area (Figure 4(a)). We can then apply a threshold filter to select the areas of the bull’s head and convert this into a binary image (Figure 4(b)). This separates the painted area from the background. At this point some pixels outside the area of interest (the bull’s head) may require editing or removing in order to further clean up or sharpen the image. Here we can see the binary image superimposed upon the original, which provides a check on the accuracy of the process. Finally, the image is reduced to its original size and work can commence on the next area selected, until the whole bull is processed.

Building up the image from two or three threshold operations will usually leave us with a good approximation of the motif (Figure 4(c)). If we then reduce this to an outline form we are able to superimpose this binary image over a variety of our preprocessed images in order to adjust the fine details of the shape (Figure 4(d)).

Discussion on the Production of the Final Binary Image

All these preprocessing stages provide us with an image ready for study and interpretation (Figure 5). A number of techniques have been used to extract the perceived information from these images. Free-hand drawing with a mouse or a pen could be an option at this stage, although the degree of subjectivity that it may include makes it unsatisfactory and it also relies on the skill of the operator. An alternative technique, used by the team at the Laboratory of Digital Image Processing and Satellite Imaging in the Department of Prehistory of CEH-CSIC in Madrid, selects pixels within the motif based on their colour (Montero Ruiz et al., 1998), thus gradually building up the recording.

We initially considered that in our approach the ideal result of the preprocessing would produce an
image to which we could apply a threshold function to convert or separate out the actual painted area from the background. In practice this use of a single process did not appear to be possible. However, the combination of multiple threshold processes using different values, or from different preprocessed images, can be used to easily and quickly build up the complete image. This also provides us with the opportunity of using different representations such as colour or shading for describing vague or unclear motifs. We are also aware that a combination of the described thresholding technique and the edge detection sequence may provide a highly detailed and objective final recording and this is one area that we intend to pursue in the future.

We should emphasize that the preprocessing is a particularly important stage within our method not only as it provides us with clearer or more readable images, but also as it allows a greater depth of the study of the relationship between the motifs and the background. In addition it provides us with a number of “reference” images with which to check the accuracy of our recording process.

Conclusions

Traditional techniques of recording entail a high degree of subjectivity due to the number of important decisions that the specialist has to take. Previous recordings on the bull of Selva Pascuala, the case study chosen in this article, are a good example of this, for the three recordings previously made show contradictory interpretations of certain features. This is not a case specific to Spain or to a particular period of rock art recording as similar cases can be found elsewhere (Moore, 1991). This is the reason for bringing into the field of rock art new recording techniques which can reduce subjectivity to a great extent. Photography and DIP combined seem to offer great advances in this area.

DIP can be seen as a technology that is perhaps far from the traditional realm of the rock art specialist. However, we consider that only the combined expertise of the rock art specialist and DIP specialist (this could be one or two people) will explore the full potential. To achieve the best results from image processing it is necessary to have not only an understanding of the nature and quality of digital imaging, i.e. resolution, grey (or colour) scale range, but also to have some knowledge of how the different processing functions operate. Because of the nature of the images with which we are dealing, and the often less than clear details within those images, it is essential that the image
processing procedure will be under the control of the rock art specialist.

In comparison with traditional techniques, the use of DIP has obvious advantages. The nature of the digital images, i.e. being composed of an array of pixels or points, facilitates the measurement of features and allows direct comparison with similar motifs in a more accurate way than traditional methods. This can obviously help discussions on style and authorship. As Vicent et al. (1997) have demonstrated, the use of digital images of rock art also allows comparison of the state of preservation which is facilitated through the superimposition of images.

In this article, we have applied the use of DIP techniques to a case study, one of the figures—a bull—of the Selva Pascuala site in Villar del Humo (province of Cuenca, Spain). The problems of traditional recording techniques of rock art were apparent in this case, for previous recordings showed distinctive contradictions (Figure 1). The use of DIP has provided a more accurate recording of the painted motif (Figure 5). The quality of the output obtained by our recording has provided a firm base from which to assess the nature and value of digital image processing techniques within the study of rock art. The result obtained confirms that the use of image processing can only add to the knowledge and interpretation of rock art, particularly as we have been able to check previously problematic areas with a detail not available with the more traditional techniques. However, despite the advantages that the results yield as compared to previous recordings, we are aware of some areas that still need further attention. As mentioned earlier in the article, there are hints of this bull being a repaint of a previous one from which the horns are the most (though extremely faint) visible remains (see Figures 1(a) & 3(a)). Further investigation of this issue could perhaps be through the use of infra-red photography, a technique to which we had no access at this stage of our research. In addition, a further field of study is the method to record some of the details that the human eye is able to discern, such as the differences of density in the paint. In particular we observed what seemed to be a thick black line especially visible—because of the higher density of paint—along the back of the animal. This outline was probably the first paint applied to the rock and the development of a method for recording which would be able to convey this information seems, therefore, necessary.

The recording of the bull of Selva Pascuala has shown the potential of DIP for the recording of rock art. As a result of our work, we would like to propose several possible ways forward in the development of this technique for the recording of pictographs. At this stage in our research, we feel that the accurate recording of density of paint seems the most urgent problem to be resolved. Other issues for future research will be a method to record perspective, something that—although it was not the case of the bull of Selva Pascuala because it was painted on a flat surface—can be a difficulty in many other examples. This is an issue that traditional techniques of recording have never resolved and that DIP together with three-dimensional modelling will undoubtedly be able to offer some answers.

Acknowledgements

We would like to thank the mayor of the council (término municipal) of Villar del Humo, D. César Ruíz Ramos, to the guide, Manuel Alcañiz García, and to a recent graduate of the University Complutense of Madrid, Marta de la Riva, for their help in their assistance in photographing Villar del Humo’s rock art. We would also like to thank the CEARA unit, and specially Octavio Collado Villalba, for allowing us to use the originals of their 1995–96 recordings of Selva Pascuala, and to María Cruz (LabTel. Laboratorio de Proceso Digital de Imagen y Teledetección Espacial. Departamento de Prehistoria, Centro de Estudios Históricos) Berrocal for her help in providing essential information for this study.

References


